

SECTION 16100

RACEWAYS, BOXES, AND CABINETS

PART 1 - GENERAL

1.1 SUMMARY

- A. This Section includes raceways, fittings, boxes, enclosures, and cabinets for electrical and communication wiring.
- B. Raceways include the following:
 - 1. Rigid metal conduit (RMC).
 - 2. Intermediate metal conduit (IMC).
 - 3. Electrical metallic tubing (EMT).
 - 4. Flexible metal conduit.
 - 5. Liquid-tight flexible conduit.
 - 6. Rigid nonmetallic conduit.
- C. Boxes, enclosures, and cabinets include the following:
 - 1. Device boxes.
 - 2. Outlet boxes.
 - 3. Pull and junction boxes.
 - 4. Cable access box

1.2 REFERENCE STANDARDS

Applicable only to the extent specified.

- A. American National Standards Institute (ANSI)
 - 1. C80.1 Rigid Steel Conduit-Zinc Coated.
 - 2. C80.3 Electrical Metallic Tubing-Zinc Coated.
 - 3. C80.6 Intermediate Metal Conduit Zinc Coated.
- B. Federal Aviation Administration (FAA)
 - 1. STD 019e Lightning Protection, Grounding, Bonding and Shielding Requirements for Facilities.
 - 2. C-1217f Electrical Work, Interior.
- C. Federal Specifications (FS)

1. W-C-586 Conduit Outlet Boxes, Bodies, and Entrance Caps.
 - D. National Electrical Contractor's Association (NECA)
 1. Standard of Installation.
 - E. National Electrical Manufacturers Association (NEMA)
 1. 250 Enclosures for Electrical Equipment.
 2. FB 1 Fitting, Cast Metal Boxes and Conduit Bodies for Conduit and Cable Assemblies.
 3. OS 1 Sheet-Steel Outlet Boxes, Device Boxes, Covers, and Box Supports
 - F. National Fire Protection Association (NFPA)
 1. 70 National Electrical Code (NEC)
 - G. Occupational Safety and Health Administration (OSHA)
 1. 1910.7 Nationally Recognized Testing Laboratories (NRTL)
 - H. Underwriters Laboratories (UL)
 1. 1 Flexible metal conduit.
 2. 6 Rigid Metal Conduit.
 3. 50 Enclosures for Electrical Equipment.
 4. 360 Liquid-tight Flexible Metal Conduit.
 5. 486A Wire Connectors and Soldering Lugs for Use with Copper Conductors.
 6. 514A Metallic Outlet Boxes.
 7. 514B Fittings for Conduit and Outlet Boxes.
 8. 797 Standard for Safety Electrical Metallic Tubing.
 9. 870 Standard for Safety Wireways, Auxiliary Gutters and Associated Fittings.
 10. 1242 Intermediate Metal Conduits.
 - I. Uniform Building Code (UBC)
- 1.3 SYSTEM DESCRIPTION
- A. Conduit size is indicated on Drawings. Minimum size conduit shall be 3/4 inch diameter.
 - B. Each critical power circuit shall occupy one dedicated conduit or box, separated from other circuits.
- 1.4 SUBMITTALS

- A. Shop drawings for nonstandard boxes, enclosures, and cabinets. Include layout drawings showing components, wiring, supports, and seismic bracing.

1.5 QUALITY ASSURANCE

- A. Comply with NFPA 70 "National Electrical Code" for components and installation.
 - 1. Boxes shall be sized in accordance with NEC Article 370.
- B. Listing and Labeling: Provide products specified in this Section that are listed and labeled.
 - 1. The Terms "Listed and Labeled": As defined in the "National Electrical Code," Article 100.
 - 2. Listing and Labeling Agency Qualifications: A NRTL as defined in OSHA Regulation 1910.7.
- C. Comply with NECA "Standard of Installation."
- D. Coordinate layout and installation of raceway and boxes with other construction elements to ensure adequate headroom, working clearance, and access.

PART 2 - PRODUCTS

2.1 GENERAL

- A. Enclosures shall conform to NEMA standards.
- B. All materials procured under this specification shall be in accordance with FAA C-1217f and FAA STD-019e.

2.2 METAL CONDUIT AND TUBING

- A. Rigid Steel Conduit: ANSI C80.1 and UL 6.
- B. Intermediate Metal Conduit: ANSI C80.6. Use for essential power systems where permitted by Code.
- C. Electrical Metallic Tubing and Fittings: ANSI C80.3 and UL 797 with compression-type fittings. (Screw type fittings are not acceptable). Use for lighting, building power, fire alarm, environmental and communication circuits in concealed areas, such as: suspended ceilings, furred walls, raised floors, and where these circuits are not subject to physical damage.
- D. Flexible Metal Conduit, Zinc Coated steel: UL 1 and FS WW-C-566
 - 1. Liquid-tight Flexible Metal Conduit: Flexible metal conduit with PVC jacket: UL 360

2. Provide flexible metal conduit in minimum 24 inches or 10 diameter lengths for connection to motors and equipment subject to vibration and movement.
 2. Conduit and fittings shall be type listed for grounding.
- E. Fittings: NEMA FB 1 and UL 514B, compatible with conduit/tubing materials. Conduit expansion and deflection fittings shall be watertight. Fabricate from material compatible with conduit to be used. Expansion and deflection fittings shall be equipped with bonding jumper cable to provide electrical continuity. Lock-nut and bushings inside boxes or enclosures shall be grounding type.

2.3 OUTLET AND DEVICE BOXES

- A. Sheet Metal Boxes: NEMA OS 1 and UL 514A.
- B. Cast Metal Boxes: NEMA FB 1, type FD, cast ferroalloy box with threaded nubs, and with gasket cover.
- C. Exposed Outlet Boxes: UL 514A steel, malleable iron or cast iron boxes with threaded conduit entry for surface mounting in areas having exposed conduit systems.
- D. Flush Outlet Boxes: UL 514A hot-dip galvanized steel, square or rectangular, 2-1/8 inches deep by four inches square, with extension ring where necessary.
- E. Boxes for lighting fixtures: Flush mounted or in concealed areas: octagonal, four inches by 2-1/8 inches deep, galvanized steel, with fixture stud supports and attachments to properly support ceiling and bracket type lighting fixtures. Surface mounted: malleable or cast iron boxes with threaded conduit hub.
- F. Sheet Metal Boxes: UL 514B.

2.4 PULL AND JUNCTION BOXES

- A. Small Sheet Metal Boxes: NEMA OS 1 and UL 514A.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine surfaces to receive raceways, boxes, enclosures, and cabinets for compliance with installation tolerances and other conditions affecting performance of the raceway system. Do not proceed with installation until unsatisfactory conditions have been corrected.
- B. Examine raceways prior to installation. No crushed or deformed raceway shall be installed.

3.2 WIRING METHODS

A. Indoors: Use the following wiring methods:

1. Connection to Vibrating Equipment (including transformers, hydraulic, pneumatic, or electric solenoid or motor-driven equipment): Flexible metal conduit, except in wet or damp locations use liquid-tight flexible metal conduit.
2. Damp or Wet Locations: Rigid metal conduit.
3. Exposed: Rigid metal conduit.
4. Concealed: Electrical metallic tubing, intermediate metal conduit, rigid steel conduit (EMT shall only be used for lighting receptacles, communications, fire alarm, security, and environmental controls in concealed locations indoors).
5. Boxes and Enclosures: NEMA Type 1, except in damp or wet locations use NEMA Type 3.

B. Outdoors: Use the following wiring methods:

1. Exposed: Rigid or intermediate metal conduit.
2. Concealed: Rigid or intermediate metal conduit.
3. Underground, Single Run: PVC coated rigid galvanized steel conduit and fittings.
4. Underground, Grouped: PVC coated rigid galvanized steel conduit and fittings.
5. Connection to Vibrating Equipment (including transformers and hydraulic, pneumatic, or electric solenoid or motor-driven equipment): Liquid-tight flexible metal conduit.
6. Boxes and Enclosures: NEMA Type 3R or Type 4.

C. Conduit Use:

1. Install rigid steel conduit (RMC) or intermediate metal conduit (IMC) for all distribution panel feeders, transformer feeders, motor control center feeders, and distribution switchboards.
2. Install electrical metallic tubing (EMT) for communication, lighting, and branch circuits.

3.3 INSTALLATION

A. Products shall be installed in accordance with FAA C-1217f and FAA STD-019e.

B. Install raceways, boxes, enclosures, and cabinets as indicated, according to manufacturer's written instructions. Install to withstand forces for the UBC Seismic Zone indicated in Section 16050, 'Basic Electrical Materials and Methods.'

C. Minimum size raceway shall be 3/4 inch, unless otherwise noted. Conduit for signal systems shall be as follows:

1. 1/2-inch conduit may be used for lengths not exceeding 50 feet. 3/4-inch conduit may be used for lengths not exceeding 100 feet.
2. 1-inch conduit shall be used for lengths exceeding 100 feet.

3. No run shall contain more than two (2) 90 degree bends, or the equivalent.
 4. Provide pull and junction boxes required to meet the above criteria.
- D. Conceal conduit and EMT, unless otherwise indicated, within finished walls, ceilings, and floors/raised floors.
1. Raceways shall not be attached to the ceiling suspension system.
 2. Raceways shall not be attached to or supported by roof decks.
 3. Do not anchor or strap raceways to wall furring channels or to other raceways.
- E. Keep raceways at least 6 inches away from parallel runs of flues and steam or hot water pipes. Install horizontal raceway runs above water and steam piping.
- F. Install raceways level and square and at proper elevations. Provide adequate headroom.
1. Install conduit to drain moisture to nearest outlet or pull box.
- G. Complete raceway installation before starting conductor installation.
- H. Support raceways and boxes as specified in Section 16050 "Basic Electrical Materials and Methods."
1. Boxes for fixtures on suspended ceilings shall be supported independently of the ceiling supports.
 2. Boxes shall not be supported from sheet-metal roof decks.
- I. Use temporary closures to prevent foreign matter from entering raceway.
1. Prevent the lodgment of plaster, dirt, or trash in raceways, boxes, fittings, and equipment during construction. Clogged raceways shall be entirely freed of obstructions or replaced. Clean each conduit run before pulling in conductors.
- J. Make bends and offsets so the inside diameter is not reduced. Unless otherwise indicated, keep the legs of a bend in the same plane and keep the straight legs of offsets parallel.
1. Prevent Bends in conduit that is 1 inch and larger shall have a minimum inside radii 12 times the nominal conduit diameter.
 2. No run shall contain more than four (4) 90 degree bends, or the equivalent. Provide pull and junction boxes required to meet the bends criteria.
- K. Use raceway fittings compatible with raceway and suitable for use and location. For intermediate steel conduit, use threaded rigid steel conduit fittings, except as otherwise indicated.

- L. Run concealed raceways with a minimum of bends in the shortest practical distance considering the type of building construction and obstructions, except as otherwise indicated.
- M. Floor and Wall Penetrations:
 - 1. Penetrations through walls or floors shall be sealed to prevent moisture and rodent entry and to deter air transfer.
 - 2. Seal penetrations of walls which separate individually temperature or humidity controlled areas, to prevent air circulation.
- N. Install exposed raceways parallel to or at right angles to nearby surfaces or structural members, and follow the surface contours as much as practical.
 - 1. Run parallel or banked raceways together, on common supports where practical.
 - 2. Make bends in parallel or banked runs from same center line to make bends parallel. Use factory elbows only where they can be installed parallel; otherwise, provide field bends for parallel raceways.
- O. Join raceways with fittings designed and approved for the purpose and make joints tight.
 - 1. Use bonding locknuts and bushings at connections subject to vibration. Use bonding jumpers where joints cannot be made tight.
 - 2. Use insulating bushings for all conduits to protect conductors.
 - 3. Provide expansion fittings for all raceways passing through the building expansion joints and conduit runs longer than 300 feet.
- P. Where knockouts are used, provide double locknuts, one on each side with a grounding bushing or grounding locknut used on the inside.
- Q. Raceway Supports: Comply with NFPA 70 and the following requirements:
 - 1. Conform to manufacturer's recommendations for selecting and installing supports.
 - 2. Install individual and multiple raceway hangers and riser clamps to support raceways. Provide U bolts, clamps, attachments, and other hardware necessary for hanger assembly and for securing hanger rods and conduits.
 - 3. Support parallel runs of horizontal raceways together on trapeze-type or bracket-type hangers.
 - 4. Spare Support Capacity: Size supports for multiple conduits so capacity can be increased by a 25 percent minimum in the future.
 - 5. Support individual horizontal raceways with separate, malleable iron pipe hangers or clamps.
 - 6. Hanger Rods: 1/4-inch diameter or larger threaded steel, except as otherwise indicated.
 - 7. Spring Steel Fasteners: Specifically designed for supporting single conduits or tubing. Might be used malleable iron hangers for 1-1/2 inch and smaller raceways serving lighting and receptacle branch circuits above suspended ceilings and for fastening raceways to channel and slotted angle supports.

8. In vertical runs, arrange support so that the load produced by the weight of the raceway and the enclosed conductors is carried entirely by the conduit supports, with no weight load on raceway terminals. Install supports simultaneously with raceway.
9. Strength of each support shall be adequate to carry present and future load multiplied by a safety factor of at least four. Where this determination results in a safety allowance of less than 200 lbs., provide additional strength until there is a minimum of 200 lbs. safety allowance in the strength of each support.
10. Space supports for raceways in accordance with Table 1 of this section. Space supports for raceway types not covered by the above in accordance with the National Electrical Code (NEC).
11. Support exposed and concealed raceway within 1 foot of an unsupported box and access fittings. In horizontal runs, support at the box and access fittings may be omitted where box or access fittings are independently supported and raceway terminals are not made with chase nipples or thread less box connectors.

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TABLE 1: SPACING FOR RACEWAY SUPPORTS

HORIZONTAL RUNS

Raceway Size (Inches)	No. of Conductors in Run	Location	RMC & IMC (1)	EMT (1)	RNC (1)
3/4	1 or 2	Flat ceiling or wall.	5	5	3
3/4	1 or 2	Where it is difficult to provide supports except at intervals fixed by the building construction.	7	7	....
3/4	3 or more	Any location.	7	7	....
1	3 or more	Any location.			....
1 & larger	1 or 2	Flat ceiling or wall.	6	6	....
1 & larger	1 or 2	Where it is difficult to provide supports except at intervals fixed by the building construction.	10	10	....
1 & larger	3 or more	Any location.	10	10	....
3/4 and larger	....	Concealed.	10	10	....

VERTICAL RUNS

No. of Raceway Size (Inches)	RMC & Conductors in Run	Location	IMC (1,2)	EMT (1)	RNC (1)
3/4	Exposed.	7	7	....
1, 1-1/4	Exposed.	8	8	....
1-1/2 and larger	Exposed.	10	10	....
Up to 2	Shaftway.	14	10	....
2-1/2	Shaftway.	16	10	....
3 & larger	Shaftway.	20	10	....
3/4 & larger	Concealed.	10	10	....

NOTES: (1) Maximum spacing of supports (feet).
(2) Maximum spacings for IMC above apply to straight runs only. Otherwise the maximums for EMT apply.

ABBREVIATIONS: EMT Electrical metallic tubing.
IMC Intermediate metal conduit.
RMC Rigid metal conduit.
RNC Rigid Non-metallic Conduit.

- R. Miscellaneous Supports: Install metal channel racks for mounting cabinets, panel-boards, disconnects, control enclosures, pull boxes, junction boxes, and other devices except where components are mounted directly to structural features of adequate strength.
- S. In open overhead spaces, cast boxes threaded to raceways need not be separately supported, except where used for fixture support; support sheet-metal boxes directly from the building structure or by bar hangers. Where bar hangers are used, attach the bar to raceways on opposite sides of the box and support the raceway with an approved fastener not more than 24 inches from the box.
- T. Sleeves: Install for cable and raceway penetrations of concrete slabs and walls, except where core-drilled holes are used. Install for cable and raceway penetrations of masonry and fire-rated gypsum walls and of all other fire-rated floor and wall assemblies. Install sleeves during erection of concrete and masonry walls.
- U. Firestopping: Apply to cable and raceway penetrations of fire-rated floor and wall assemblies. Perform firestopping as specified in Section 07840 "Fire-Stopping" to reestablish the original fire-resistance rating of the assembly at the penetration.
- V. Fastening: Unless otherwise indicated, fasten electrical items and their supporting hardware securely to the building structure, including but not limited to conduits, raceways, cables, cabinets, panelboards, boxes, disconnect switches, and control components in accordance with the following:
 - 1. Fasten by means of wood screws or screw-type nails on wood; toggle bolts on hollow masonry units; concrete inserts or expansion bolts on concrete or solid masonry; and by machine screws, welded threaded studs, or spring-tension clamps on steel.
 - 2. Threaded studs driven by a powder charge shall not be used.
 - 3. Welding to steel structure may be used only for threaded studs, not for conduits, pipe straps, or any other items.
 - 4. In partitions of light steel construction use sheet-metal screws.
 - 5. Drill holes in concrete beams so holes more than 1-1/2 inches deep do not cut main reinforcing bars.
 - 6. Drill holes in concrete so holes more than 3/4 inch deep do not cut main reinforcing bars.
 - 7. Fill and seal holes drilled in concrete and not used.
 - 8. Select fasteners so the load applied to any fastener does not exceed 25 percent of the proof-test load. Use vibration and shock-resistant fasteners for attachments to concrete slabs.
- W. Terminations: Where raceways are terminated with locknuts and bushings, align the raceway to enter squarely, and install the locknuts with dished part against the box. Use two locknuts, one inside and one outside the box, where terminations cannot be made secure with one locknut. In addition a bushing shall be installed on the interior threaded end of the conduit to protect conductor insulation.

- X. Where terminating in threaded hubs, screw the raceway or fitting tight into the hub so the end bears against the wire protection shoulder. Where chase nipples are used, align the raceway so the coupling is square to the box, and tighten the chase nipple so no threads are exposed.
- Y. Make raceway terminations tight. Use bonding bushings or wedges at connections subject to vibration. Use bonding jumpers where joints cannot be made tight. Use insulating bushings to protect conductors.
- Z. Install pull wires in empty raceways. Use No. 14 AWG zinc-coated steel or monofilament plastic line having not less than 200-lb. tensile strength. Leave not less than 12 inches of slack at each end of the pull wire.
- AA. Flexible Connections: Use maximum of 6 feet of flexible metallic conduit for recessed and semi-recessed lighting fixtures; for equipment subject to vibration, noise transmission, or movement; and for all motors. Use liquid-tight flexible metallic conduit in wet or damp locations. Install separate ground conductor across flexible connections.
- BB. Metal conduits shall be mechanically and electrically continuous between outlets, junctions and pull boxes, panels, cabinets and similar equipment.
- CC. Conduits shall enter and be secured to enclosures so that each system is electrically continuous throughout.
- DD. Provide grounding connections for raceway, boxes, and components as indicated and instructed by manufacturer. Tighten connectors and terminals, including screws and bolts, according to equipment manufacturer's published torque-tightening values for equipment connectors. Where manufacturer's torque requirements are not indicated, tighten connectors and terminals according to tightening torques specified in UL Standard 486A.
- EE. Provide conduit support members required for proper and secure installation. Include stud supports, stems, mounting brackets, frames, and, if applicable, plaster rings.
 - 1. Conduit supports shall employ materials which are suitable for the purpose. Cast metal parts other than malleable iron and cast-on rolled threads shall be designed to ensure structural adequacy.
- FF. Field Cut Conduit: Where conduit has to be cut in the field, it shall be cut square using a hand or power hacksaw or approved pipe cutter using cutting knives. The cut ends of the field-cut conduit shall be reamed to remove burrs and sharp edges. Where threads have to be cut on conduit, the threads shall have the same effective length and shall have the same thread dimensions and taper as specified for factory-cut threads on conduit.

3.4 INSTALLATION - BOXES

- A. Boxes: Shall be provided in the wiring or raceway system for pulling wires, making connections, and mounting devices or fixtures. Each box shall have the volume required by NFPA 70 for the number and size of conductors in the box.
 - 1. Outlet boxes: Each outlet box shall have a machine screw which fits into a tapped hole in the box for the ground connection.
 - 2. Mounting light fixtures: Boxes for mounting fixtures shall be not less than 4 inches square.
 - 3. Concealed wiring: Boxes installed for concealed wiring shall be provided with extension rings or plaster covers. The front edge of the box shall be flush or recessed not more than 1/4" from the finished wall surface (whether the finished surface is drywall, or drywall and a sound-absorbing material).
 - 4. Boxes in masonry block or tile walls: Shall be square-cornered tile-type, or standard boxes shall have square-cornered tile-type covers.
 - 5. Wet locations: Cast metal boxes installed in wet locations and boxes installed flush with exterior surfaces shall have gasket.
- B. Fixture boxes: Attach boxes to ceilings which are not suspended in at least two places. Distribute lighting fixture load over the ceiling boxes.
- C. Mounting:
 - 1. Install switch box on the strike side of the door at mounting height of 48 inches. Unless otherwise indicated, mounting height of receptacle boxes shall be 18 inches.
 - 2. Height of a wall mounted outlet box is defined as the height from finished floor to horizontal center line of the cover plate.
 - 3. Where outlets are indicated adjacent to each other, mount outlets in a symmetrical pattern with tops at the same elevation. Where outlets are indicated adjacent, but with different mounting heights, line up outlets on a vertical line.
 - 4. Verify the final location of each outlet before installation. Remove and relocate outlet boxes placed in an unacceptable position.
 - 5. At fire rated partitions, offset boxes to prevent back-to-back installation.
- D. Box openings: Provide only the openings necessary to accommodate the conduits at the individual location. When this is not practical, plug unused openings.
- E. Junction, transition and pull boxes:
 - 1. Install junction, transition and pull boxes so that covers are readily accessible. Boxes in concealed areas of ceiling or wall shall be accessible through removable panels.
 - 2. Locate pull boxes to permit easy pulling of wire or cables.
 - 3. Securely attach boxes to structural and framing members using compatible fasteners of adequate size.
 - 4. Bolt wall mounted boxes to steel profiles fastened to the wall.

- F. Grounding: Provide each box with a green machine screw. Screw into tapped hole in the box for ground wire or lug connection.

3.5 PROTECTION

- A. Provide final protection and maintain conditions, in a manner acceptable to manufacturer and Installer, to ensure that coatings, finishes, and cabinets are without damage or deterioration at Substantial Completion.
 - 1. Repair damage to galvanized finishes with zinc-rich paint recommended by manufacturer.
 - 2. Repair damage to PVC or paint finishes with matching touch-up coating recommended by the manufacturer.
- B. Cap stubbed up raceways, including raceways in cabinets, immediately upon installation. The use of paper or rag wads is not acceptable.
- C. Galvanic corrosion protection: Avoid dissimilar metals in contact anywhere in conduit runs. Where contact cannot be avoided at conduit terminations, treat the connection with joint compound that eliminates galvanic corrosion. Where dissimilar metals are in contact: such as at aluminum cable tray or enclosures and steel supports, separate contact surfaces by using gaskets, non-absorptive tape, or coating to prevent galvanic corrosion.

3.6 CLEANING

- A. Upon completion of installation of system, including outlet fittings and devices, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finish, including chips, scratches, and abrasions.

END OF SECTION 16100